An Invention for giving perfectly uniform Rotary Motion in Driving Clocks. By H. C. Russell, Esq., Director of the Sydney Observatory.

The Clock now to be described was designed to give uniform motion to a Barrel-Chronograph, and the result is perfectly satisfactory; so much so that the driving weight may be varied 30 per cent. without producing *any change* in the rate.

I have applied the same form of governor to a telescope clock, and it keeps a star on the wire as if it formed part of it; and there is good reason to suppose that the same governor applied to the train of a standard clock would give better results than any yet obtained from the single pendulum.

These are strong statements; but they will, I think, be confirmed by what follows:—

In design the clock is very simple, and it seems strange that a similar arrangement was not long since devised. It will be easily understood by the aid of the following short description and two diagrams.

Fig. I. is a general view of the clock, showing the train of wheels, ending in a pair of bevel wheels at the top of the clock case. The object of these is to make the escape wheel axis vertical, and to have it project through the top of the clock case at N enough to carry the wheel D (Figs. I. and II.) and the parts attached to it, which are (1) the arm A (Fig. II.) projecting from the first wheel in the train; (2) the spring B; (3) a small train of wheels C, ending in a fan-fly which makes two hundred revolutions for one of the first wheel J; (4) projecting up from the arm A at the point E is a small steel pin half an inch long, which, when at rest, forms a continuation of the axis of the wheel D, but when in motion leaves the centre, taking the arm A and thus turning the wheel J and setting the fan in motion. This pin E forms the connection between the clock train and the pendulums, for it works in a hole in the lower end of the rod K, and this is connected with each of the pendulums by the rods H, H, H, H; they are fastened to K by small steel springs, and to the pendulum rods by small ball and socket joints. The rod K, together with part of the weight of the rods H, H, H, H, is held up by a steel wire at G.

The axis of the wheel J and the arm A is a steel pin fixed to, and standing up vertical from, the surface of the wheel D; the arm A therefore moves in a plane parallel to the surface of D, and when it leaves the position shown in the drawing it carries the pin E along the dotted curve EO, E being always vertical. In moving from the centre, E bends the light steel spring B, which acts as a resisting force to the increase of its eccentricity. It is obvious that if E moves slowly the wheels and fan will offer very little, if any, resistance; but it cannot be moved suddenly, owing to the resistance offered by the train and fan. The

Fig. 1.

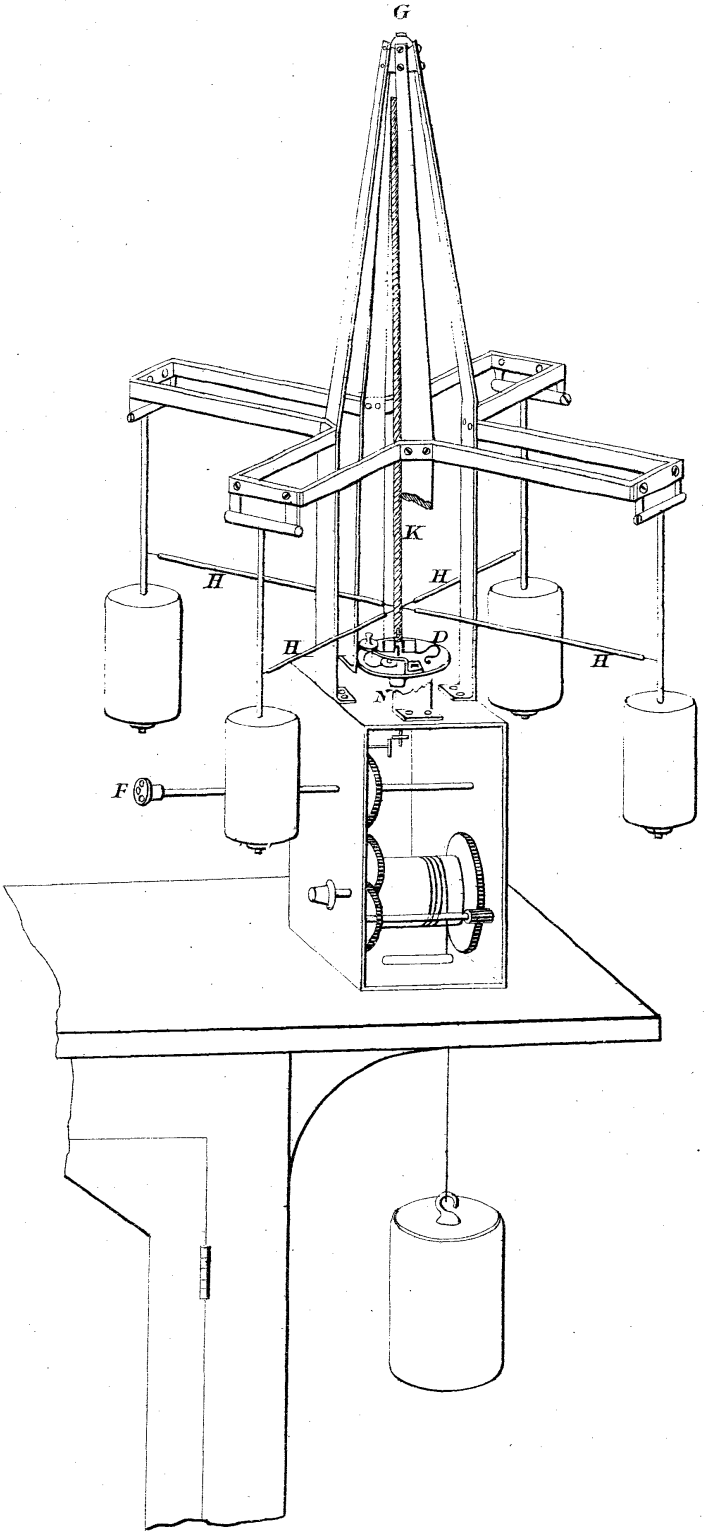

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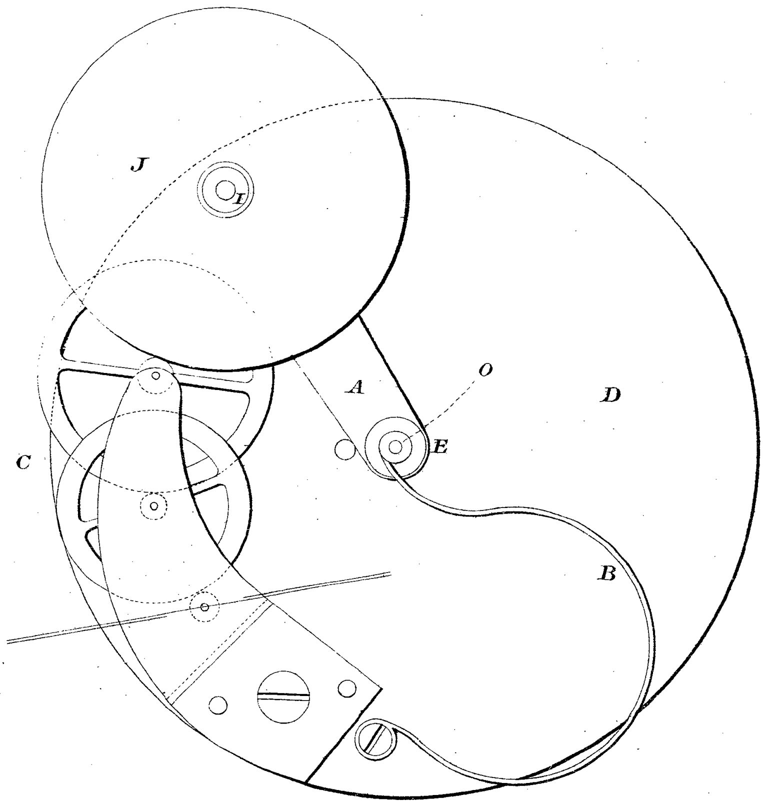
Fig. 2.



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strength of the spring B must be learned by experiment; if it is too strong, the clock will gain with increased weight, and if it is too weak the clock will lose under the same conditions. The one in use in this clock is about as strong as the balance spring in an American clock.

There is nothing unusual about the pendulums, except that they are hung by two springs instead of one; the bobs are lead, and each of them weighs 15 lb.; the time is half a second. The train is an ordinary clock train, and requires no mention here.

When all the parts of this clock are in the position shown, and a weight is applied to the driving barrel, the wheel D begins to move, and a slight impulse given to one of the pendulums pushes the pin E from the centre of D, and it at once sets the other three pendulums in motion, and their arcs gradually increase until the force necessary to drive them is equal to the driving weight. Should the weight be increased, the pendulum arcs, and with them the eccentricity of E, increase until equilibrium is again attained. Now, if the experiment of increasing the weight be tried without the spring B, the clock will be found to go slower, like an ordinary pendulum clock under increased weight; but if the spring B be carefully adjusted, 30 per cent. added to the weight will not produce *any change in rate*, even when the test is a first-class sidereal clock marking the chronograph cylinder every second, a test which, as is well known, would at once show the smallest change of rate.

One difficulty, which in the earlier experiments promised to be a very serious one, was overcome by introducing the small train of wheels. It was this: if all the pendulums were not perfectly isochrone, the pin E would very soon cease to move in a circle, and would describe an ellipse, and have therefore an *irregular* rotary motion. Independent of the difficulty of making four pendulums isochrone, it is necessary that the escapement should have in it something to prevent the pin E from moving in an ellipse, and such the train of wheels and fan provide, because they strongly resist sudden changes of eccentricity, at the same time that they allow slow changes, such as those caused by friction, to go on with little or no resistance. In this is involved an important principle, viz.: If the pendulums are not isochrone, the time given in each revolution of the escape wheel is the *mean* of the times of a double oscillation for each pendulum. So that, if four nearly compensated pendulums in a standard clock were thus connected, the rate under changes of temperature would be the mean of the four rates. And since the spring, as before shown, counteracts the effect of changes in the friction or driving power, there is good reason to suppose that such a clock would keep better time than a clock with only one pendulum, subject to the many changes of impulse given to it by the train.

Such is the clock now used to work the barrel chronograph from which the sample sheets sent herewith have been taken.

Some of these have been run without change of weight, in one the weight has been changed twice, in another only one change; but I have confined the experiments so far to a change of 30 per cent. in the driving weight, because they take so much time to make them.

It is necessary to add that this clock is the first made of the kind, and the wheels are old ones adapted to the requirements; but in some of them imperfections are known to exist, and these appear as slight errors in the seconds marks. I have been obliged to send out of the colony to get the wheels made with the accuracy required, and it will be some time before the clock intended for the chronograph is made; but the results with this rough experimental clock are so good that I thought they ought to be published.

Four pendulums are not essential; two give very good results provided the arms H be not too short, say not less than 12 inches. Such a clock I have applied to the $11\frac{1}{2}$-inch Equatoreal, and the motion is perfect, keeping a star on the wire as if it were part of it, so long as changing refraction does not interfere. By a very simple contrivance the rate is changed to suit the Moon or planets. This is effected by continuing the pendulum rods two inches below the bobs and fixing brass disks on the end of them; upon these weights can be placed having a known effect upon the rate, and for convenience they are stamped with the number of seconds change they produce in ten minutes; so that it is only necessary to look at the *Nautical Almanac* and see the Moon's change in R.A. in ten minutes, and select these weights, in order to make the telescope follow the Moon exactly.

A few words about the origin of the clock may not be out of place here. Last year a new barrel chronograph was required for Sydney Observatory, and Mr. William Barraclough, of Sydney, undertook to make it. When the cylinder and pen carriage were completed, experiments were made with several well-known forms of governor, in order to secure uniform rotation of the cylinder. None of these would give such uniform motion as I required; and Mr. Barraclough said that some years since, when in England, he had been asked to make a clock that would not *tick*, and that after some trouble he had succeeded, using only one pendulum; but that he thought he could make perfectly uniform motion with two oscillating pendulums, and at my request he made a rough model with two pendulums working at right angles to each other. Each pendulum was connected with the eccentric pin by means of a double (Watt's) parallel motion, so arranged that the part of the rod connected with E moved in a straight line parallel to the surface of the wheel D; and the motion of the eccentric pin was made stiff by means of a cloth washer under the arm A; this obliged E to move in a circle, and at the same time allowed the pendulum arcs to increase if necessary. This model proved that it was possible to get smooth rotary motion from two oscillating pen-

dulums; but when it came to be tested for uniform rotation, I found the friction of the cloth washer so uncertain that the governor was of little value. Several other forms of friction under the arm A gave a like result: without any friction under A, elliptical motion was always sooner or later set up by the pin E, and at one time I almost gave up hope of overcoming the difficulty; for these experiments made it obvious that E must be *free* to move and yet have some *resistance to sudden change of position*, so that it could not move in an ellipse. I then devised the small train and fan-fly to meet these requirements, and the four straight rods connecting the pendulums with the rod K, instead of the rather complex parallel motion of the model. In its present form the clock seems only to require for its perfection that the spring B shall not be changed by change of temperature, and this I have no doubt can be accomplished by making it of a particular length and form.

I have purposely avoided dimensions, because these may be varied at pleasure. For instance, seconds pendulums may be used and the wheel D would then turn in two seconds; but I prefer and have used half-seconds pendulums. So the weight of the pendulums and the strength of their supporting springs may vary; but it is not desirable to have the supporting springs stronger than is necessary to carry the weight. The only dimension that perhaps ought to be given is the length of the rods H. If these are short they do not work well. Those I have in use are nine inches long, and they would work better if longer, because they would then move near the direction of the swing of the pendulum and not tend to twist it so much, as they move from side to side with the eccentric.

Sydney Observatory,
1879, *March* 18.

On the Applicability of the Mean Refractions of Bessel's "Fundamenta" to the Washington Observations. By A. M. W. Downing, Esq.

As it appears from recent investigations, the results of which are exhibited in an Addendum to the Introduction to the Greenwich Nine-Year Catalogue, that the refractions of the *Tabulæ Regiomontanæ* unaltered, at all events as far as 85° Z.D., represent fairly enough the Greenwich observations, I thought that it would be interesting to try whether the N.P.D.'s of the Washington Catalogue for 1860 are in satisfactory accord with observations made in the Southern Hemisphere, as these N.P.D.'s are reduced with the refractions of the *Tabulæ* unaltered. I have